

HYDROLIGHT TECHNICAL NOTE 4

THE RADTRAN-X ATMOSPHERIC IRRADIANCE MODEL



The RADTRAN atmospheric irradiance model, developed by Gregg and Carder (1990), was designed to provide quick and accurate predictions of direct solar and diffuse sky spectral irradiances onto the sea surface, given atmospheric conditions such as aerosol type, water vapor and ozone concentrations, solar angle, etc. I have compared RADTRAN predictions with measurements and it works very well, even for difficult situations such as the sun near the horizon. The database underlying the original RADTRAN model covered wavelengths from 350 to 700 nm, which is the range relevant for photosynthesis. This database was extended to 800 nm and the resulting RADTRAN model was adopted in HydroLight version 4 as the default model for computing the downwelling plane irradiance onto the sea surface, which sets the magnitude of the in-water and water-leaving radiances as computed by HydroLight.

The underlying database has been revised and extended by Dr. Marcos Montes of the Naval Research Laboratory (personal communication) to cover 300-1000 nm for use in HydroLight-EcoLight version 5.0. These notes briefly describe his extension, which I call RADTRAN-X, for RADTRAN-eXtended.

The needed information on the extra-terrestrial solar irradiance, and absorption by ozone, oxygen, and water vapor, was obtained from various high-spectral-resolution databases:

Solar irradiance: converted from MODTRAN 3.5

Ozone absorption: derived from LOWTRAN 7

Oxygen and water vapor absorption: derived from line-by-line code developed by W. Ridgway at NASA-GSFC.

In each case these high-resolution data were processed with Gaussian spectral response functions with a 0.2 nm FWHM at 0.1 nm spacing to obtain data at 0.1 nm resolution. To obtain a revised database for use at 1 nm resolution with the original RADTRAN code, the 0.1 nm data were averaged by an approximately boxcar filter centered on the nominal wavelength. Thus 10 Gaussians at 0.1 nm resolution were averaged to get each RADTRAN-X database value at 1 nm resolution. The resulting database shows higher spectral resolution than does the original RADTRAN database, which appears to have been processed with a wider filter function. The differences are seen in Fig. 1, which compares RADTRAN and RADTRAN-X total irradiances for a particular set of atmospheric conditions (solar zenith angle = 45 deg; sea level atmospheric pressure = 29.92 in Hg; air mass type 5; relative humidity 80%; 1.5 cm precipitable water; 15 km horizontal visibility; 6 m s⁻¹ current and 24-hour-average wind speeds; and ozone concentration = 350 Dobson units).

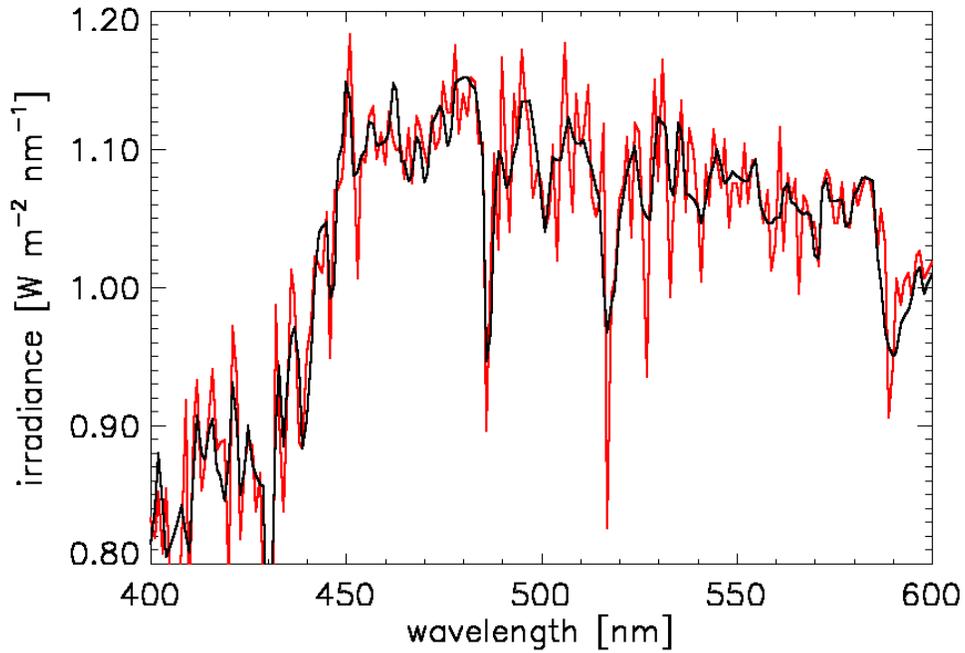


Fig. 1. Comparison of RADTRAN (black) and RADTRAN-X (red) total downwelling plane irradiances at 1 nm resolution for a particular set of atmospheric conditions.

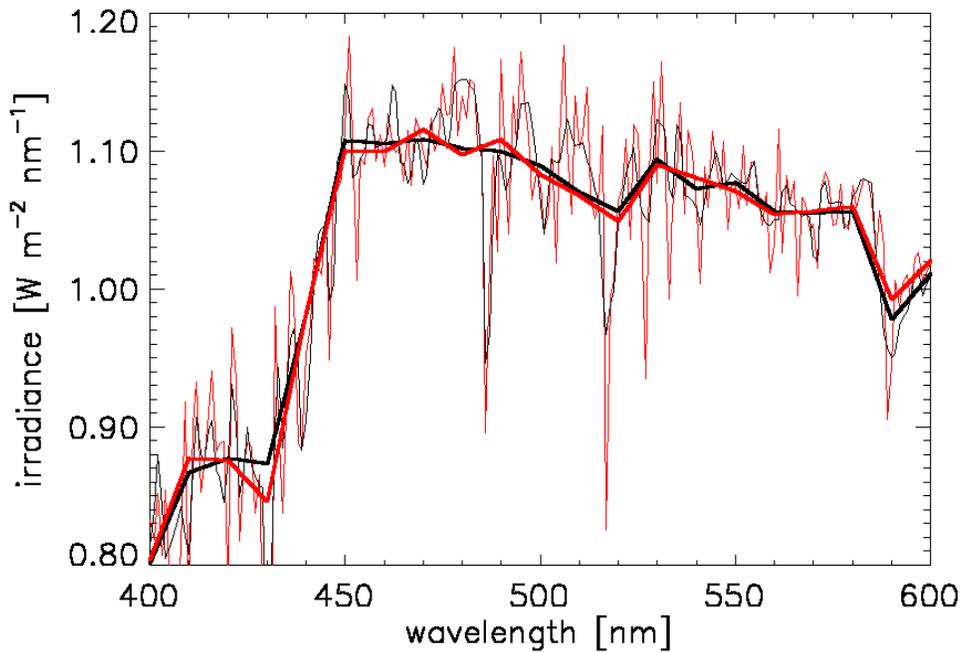


Fig. 2. Comparison of RADTRAN (black) and RADTRAN-X (red) total downwelling plane irradiances band averaged to 10 nm resolution (heavy lines overlying the 1 nm data of Fig. 1).

However, when the 1 nm resolution irradiances are averaged over wider bandwidths, as is common in Hydrolight runs, the differences in RADTRAN and RADTRAN-X are less noticeable. Figure 2 shows, for example, the irradiances of Fig. 1 averaged over 10 nm bands. The differences in the RADTRAN and RADTRAN-X 10 nm band averages are less than one percent except where a particularly deep solar Fraunhofer line or atmospheric absorption band makes the difference as large as several percent.

Figure 3 shows the RADTRAN-X total, direct, and diffuse irradiances from 300 to 1000 nm, as computed for the same atmospheric conditions as in Fig. 1. The RADTRAN values are overlaid in black for the 350-700 nm region. It should be noted that almost no solar radiation reaches the earth's surface below 300 nm.

More extensive comparisons of atmospheric models have been made than what is discussed here. The present RADTRAN-X formulation is chosen for use in HydroLight-EcoLight version 5.0 because it gives good results over the extended wavelength range, and it appears to be at least as good as RADTRAN over the 350-700 nm range.

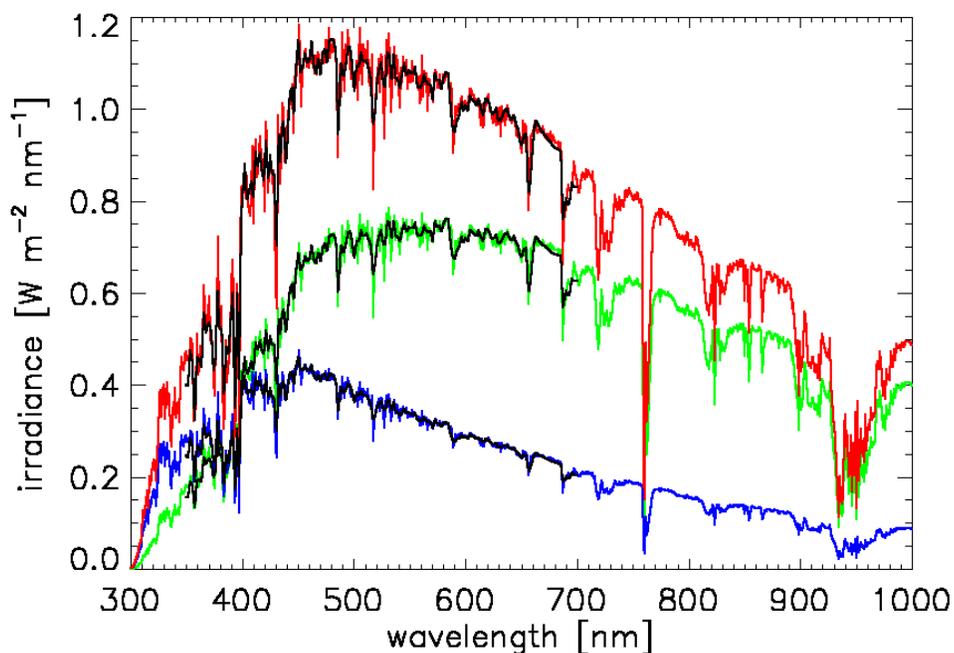


Fig. 3. RADTRAN-X computed values of the total (red), direct solar (green), and diffuse sky (blue) irradiances for the conditions of Fig. 1. RADTRAN values are overlaid in black for 350-700 nm.

The angular pattern of the sky radiance distribution is still determined using the semi-analytic formulas of Harrison and Coombs (1988). These formulas were developed from visible-wavelength radiance measurements, where the direct solar irradiance is typically greater than the diffuse sky radiance (for cloud-free skies). However, below 400 nm, the strong Rayleigh scattering makes the diffuse irradiance typically greater than the direct irradiance, as seen in Fig. 3. Thus the Harrison and Coombs sky radiance pattern is probably not accurate below ~400 nm, and perhaps above ~700 nm (where the diffuse component becomes much smaller than the direct). However, for most HydroLight applications, the angular distribution of the sky radiance is of lesser importance than the incident irradiance magnitude, which is being computed accurately by RADTRAN-X. (Needless to say, if anyone can inform me of an analytic sky radiance distribution model that is better than Harrison and Coombs, I'll be glad to incorporate it into HydroLight.)

References and Notes

Gregg, W. W. and K. L. Carder, 1990. A simple spectral solar irradiance model for cloudless maritime atmospheres. *Limnol. Oceanogr.* 35(8), 1657-1675.

Harrison, A. W. and C. A. Coombes, 1988. An opaque cloud cover model of sky short wavelength radiance. *Solar Energy*, 41(4), 387-392.

In the original RADTRAN computer code, there was an error in the computation of the climatological ozone concentration. The resulting error in the surface irradiance was usually less than one percent, which is why the error went undetected for many years. This error has been corrected in RADTRAN-X. If very accurate ozone concentrations are needed, measured values for a given date and location can often be obtained at

<http://toms.gsfc.nasa.gov/ozone/ozone.html>

http://toms.gsfc.nasa.gov/teacher/ozone_overhead.html